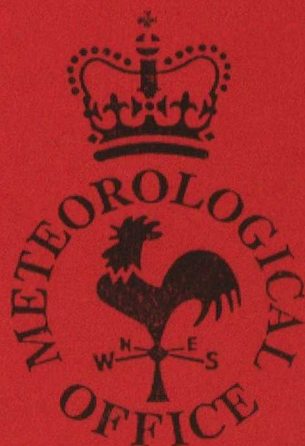




FORECASTING SYSTEMS TECHNICAL NOTE NO.4

SUMMARY of TROPICAL CYCLONE ACTIVITY and

FORECASTS in the 1995

NORTHERN HEMISPHERE SEASON

J.T.HEMING

APRIL 1996

Headquarters, Bracknell

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1. INTRODUCTION

A summary of tropical cyclone activity in the northern hemisphere for the 1995 season is presented below together with an assessment of the performance of the global model in predicting the tracks of these tropical cyclones.

Tropical cyclones are experienced in the North Pacific, North Atlantic and North Indian Oceans and nearby tropical seas. For the purpose of tropical cyclone verification the northern hemisphere is divided into four basins; the North-West Pacific (west of 180°E to the Malay Peninsula), the North-East Pacific (east of 180°E), the North Atlantic and the North Indian Ocean (west of the Malay Peninsula). Mean error statistics for each basin are presented together with a table of statistics for the whole northern hemisphere. The global model produces a 6-day forecast every 12 hours. Verification is performed at 24 hour intervals up to forecast time T+120.

The present global model has a resolution of 1.25°x 0.83°x 19 levels. This is equivalent to a horizontal resolution of 139km x 93km at the equator. The tropical cyclone verification scheme identifies the centre of a tropical cyclone in the model by locating a local maximum of relative vorticity at 850hPa. A surface fitting technique is used to locate the centre accurately.

The terms used in the statistics tables are explained below :-

- Possibly verified - No. of forecasts fulfilling requirements 1, 2 & 4 below.
- Actually Verified - No. of forecasts fulfilling *all* the requirements below(*).
- Mean DX - Mean of positional errors in the East-West direction.
- Mean DY - Mean of positional errors in the North-South direction.
- Mean AT - Mean of positional errors in the Along Track direction.
- Mean CT - Mean of positional errors in the Cross Track direction.
- Skill - Percentage skill of model against CLIPER.
- Mean DPE - Mean of direct positional errors.

All errors are measured in kilometres except where indicated.

- (*) 1. Observed maximum wind at least 31 knots at the verifying time.
- 2. Forecast tropical cyclone centre equatorwards of 40 degrees.
- 3. Forecast tropical cyclone centre relative vorticity above a critical limit for verification (0.55×10^{-4} per second).
- 4. Observation within 6 hours of verifying time present for use in verification.

Forecast skill is defined as:- $\frac{\text{CLIPER DPE} - \text{Model DPE}}{\text{CLIPER DPE}} \times 100\%$

Positive skill indicates the model forecast is better than CLIPER.

Negative skill indicates the CLIPER forecast is better than the model.

A diagrammatic explanation of other error statistics and their sign conventions can be found in Appendix A. Full details of the TC verification scheme can be found in nwp Gazette, Vol.1, No.2, December 1994.

Advisory positions from JTWC Guam, NHC Miami and CPHC Honolulu are used as verifying observations of storm location when track verification is carried out immediately after a storm has ended. Best track data from these centres has been obtained for this season's storms and the track forecasts verified again. Statistics for verification against best-track observations are presented in detail. Some statistics for verification against real-time observations are included for the purposes of a comparison. Some mean error statistics for last season are also included for the purposes of a comparison. Note, the statistics for last season were obtained using real-time verifying observations. Forecast tracks are only verified when a depression reaches tropical storm status.

2.TROPICAL CYCLONE ACTIVITY

	NWP	NEP	NAT	NI	TOTAL
Total number active 1994	39(34)	22(20)	12(7)	5(5)	78(66)
Total number active 1995	35(25)	11(10)	21(19)	4(4)	71(58)

Basin name abbreviations:- NWP = North-West Pacific (west of 180°E)
NEP = North-East Pacific (east of 180°E)
NAT = North Atlantic
NI= North Indian

The number in brackets indicates the number of depressions which reached tropical storm status (maximum sustained wind above 33 knots).

3. SUMMARY OF ALL NORTHERN HEMISPHERE STORMS

3.1 North-West Pacific Basin Storms

Table of Mean Error Statistics

	T+0	T+24	T+48	T+72	T+96	T+120
Possibly Verified	235	184	141	97	61	44
Actually Verified	235	174	124	74	44	33
Mean DX	2	18	77	150	242	369
Mean DY	10	47	92	104	83	107
Mean AT	-6	-46	-87	-125	-297	-462
Mean CT	6	19	57	104	173	295
Mean Skill (%)	****	2	23	23	****	****
* 1994 Skill (%)	****	8	27	32	****	****
RT Skill (%) #	****	24	32	28	****	****
Mean DPE	60	180	297	439	691	826
* 1994 DPE	87	200	312	443	570	699
RT DPE #	53	178	296	436	688	823

* DPE and skill for all North-West Pacific storms in 1994 season

DPE and skill in 1995 calculated using real time observations as opposed to best track.

Comments:

A plot of the observed tracks of all storms in this basin can be found in Fig. 1.

There were nine less tropical storms this season than last in the North-West Pacific basin. The distribution of the storms was unusual; most were concentrated in the South China Sea and very few in the eastern part of the basin. Forecast errors were up to 10% lower than last season at early forecast times, but were up to 21% higher at later forecast times. Skill scores were slightly lower than last season. There was an overall slow bias and a slight right-of-track bias in forecasts this season.

Tracks of tropical storms in the South China Sea are more difficult to predict than those further east because they are more likely to be undergoing recurvature. This may explain the lower skill scores this season and higher errors at longer forecast ranges. It must also be noted that despite only small differences between real time and best track positional errors this season, best track skill scores were considerably lower than real time skill scores. In fact, real time T+24 and T+48 skill scores this year were higher than in 1994.

Figs. 2 and 3 show forecast errors and skill scores for the last few seasons.

3.2 North-East Pacific Basin Storms

Table of Mean Error Statistics

	T+0	T+24	T+48	T+72	T+96	T+120
Possibly Verified	101	81	61	42	28	18
Actually Verified	101	68	40	17	8	6
Mean DX	2	37	67	153	205	370
Mean DY	3	-44	-102	-77	-51	-189
Mean AT	-4	-86	-151	-133	-179	-343
Mean CT	6	-16	26	-24	48	-18
Mean Skill (%)	****	-17	27	29	****	****
* 1994 Skill (%)	****	-69	7	26	****	****
RT Skill (%) #	****	-1	23	25	****	****
Mean DPE	56	164	259	343	358	521
* 1994 DPE	145	273	393	509	655	784
RT DPE #	46	161	260	342	356	506

* DPE and skill for all North-East Pacific storms in 1994 season

DPE and skill in 1995 calculated using real time observations as opposed to best track.

Comments :

A plot of the observed tracks of all storms in this basin can be found in Fig. 4.

There were ten less tropical storms this season than last in the North-East Pacific basin. Most of this season's storms were concentrated in the eastern part of the basin. Only one passed into the Central Pacific area. Forecast errors were 33-45% lower than last season and skill scores were higher, particularly at T+24. As for the North-West Pacific area there was an overall slow bias this season.

T+24 best track skill scores were considerably lower than real time skill scores despite only small differences between real time and best track positional errors. However, even the best track skill scores were higher than in 1994.

Figs. 5 and 6 show forecast errors and skill scores for the last few seasons.

3.3 North Atlantic Basin Storms

Table of Mean Error Statistics

	T+0	T+24	T+48	T+72	T+96	T+120
Possibly Verified	245	196	163	130	106	84
Actually Verified	245	185	145	117	85	60
Mean DX	3	-27	-50	-57	-59	-120
Mean DY	2	19	16	-34	-73	-103
Mean AT	-10	-24	-34	-69	-154	-336
Mean CT	7	-1	-22	-44	-79	-165
Mean Skill (%)	****	17	42	42	****	****
* 1994 Skill (%)	****	30	43	48	****	****
RT Skill (%) #	****	27	47	45	****	****
Mean DPE	54	144	221	323	445	593
* 1994 DPE	78	224	335	405	479	720
RT DPE #	46	145	220	323	448	591

* DPE and skill for all North Atlantic storms in 1994 season

DPE and skill in 1995 calculated using real time observations as opposed to best track.

Comments :

A plot of the observed tracks of all storms in this basin can be found in Fig. 7.

There were twelve more tropical storms this season than last in the North Atlantic basin in what was one of the most active seasons on record. Most of these storms recurved or dissipated in mid-Atlantic and relatively few made landfall, although those that did caused much devastation. Forecast errors were 7-36% lower than last season, but skill scores were lower, particularly at T+24. Once again, there was an overall slow bias this season. T+24 best track skill scores were 10% lower than real time skill scores despite only small differences between real time and best track positional errors.

Figs. 8 and 9 show forecast errors and skill scores for the last few seasons.

3.4 North Indian Basin Storms

Table of Mean Error Statistics

	T+0	T+24	T+48	T+72	T+96	T+120
Possibly Verified	21	14	8	3	0	0
Actually Verified	21	14	7	2	0	0
Mean DX	-15	-81	-196	-455	****	****
Mean DY	1	-74	-176	-233	****	****
Mean AT	3	-78	-307	-428	****	****
Mean CT	0	-49	5	-11	****	****
Mean Skill (%)	****	9	16	****	****	****
* 1994 Skill (%)	****	-74	8	29	****	****
RT Skill (%) #	****	43	41	****	****	****
Mean DPE	56	160	407	566	****	****
* 1994 DPE	83	278	370	431	709	****
RT DPE #	48	143	409	567	****	****

* DPE and skill for all North Indian storms in 1994 season

DPE and skill in 1995 calculated using real time observations as opposed to best track.

Comments :

A plot of the observed tracks of all storms in this basin can be found in Fig. 10.

There was one less tropical storm this season than last in the North Indian basin. Forecast errors were lower than last season at T+24, but higher at longer forecast ranges. Skill scores were higher than last season, particularly at T+24. At T+24, best track skill scores were much lower than real time skill scores and real time positional errors were larger than best track. Meaningful statistical comparisons from year to year are hard to make in this basin due to the small number of forecasts verified.

Figs. 11 and 12 show forecast errors and skill scores for the last few seasons.

3.5 Combined Statistics for whole Northern Hemisphere

Table of Mean Error Statistics

	T+0	T+24	T+48	T+72	T+96	T+120
Possibly Verified	602	475	373	272	195	146
Actually Verified	602	441	316	210	137	99
Mean DX	2	0	11	29	52	72
Mean DY	5	17	26	9	-21	-38
Mean AT	-7	-44	-76	-97	-201	-378
Mean CT	6	3	9	10	9	-3
Mean Skill (%)	****	7	33	35	****	****
* 1994 Skill (%)	****	-7	24	31	****	****
RT Skill (%) #	****	23	39	38	****	****
Mean DPE	57	162	260	368	519	666
* 1994 DPE	104	223	335	457	585	719
RT DPE #	49	160	259	367	520	663

* DPE and skill for all Northern hemisphere storms in 1994 season

DPE and skill in 1995 calculated using real time observations as opposed to best track.

Comments :

Forecast errors were 7-27% lower and skill scores 4-14% higher for the whole northern hemisphere in 1995 when compared to 1994. Forecast errors were also lower and skill scores higher than in any previous year. There was a slow bias in forecasts, but the right-of-track bias seen in previous years was almost totally eradicated. On average, there was only a small difference between forecast positional errors derived using real time observations and those derived using best track observations, although at T+24 best track skill scores were 16% lower than real time values.

Figs. 13 to 16 show forecast errors, skill scores, along and cross track errors over the last few seasons. 1995 was the first complete season after the introduction of a new technique for the initialisation of tropical cyclones in the global model. The results for 1994 would have been partially affected by the introduction of this new technique which took place in October 1994. However, the results for 1995 show a continued improvement over 1994 as well as previous years. For more details of the new initialisation technique see the following publication:-

"A new scheme for the initialisation of tropical cyclones in the UK Meteorological Office global model" by J.T.Heming, J.C.L.Chan and A.M.Radford (1995). Meteorological Applications, 2, 171-184.

Further Tropical Cyclone Information

The Met. Office pages on the World Wide Web contain information on tropical cyclone forecasting at the Met. Office. Monthly bulletins of tropical cyclone activity and forecasts are held together with observed and forecast track information of recent storms, track prediction error statistics, lists of names, images, movies and photographs and details of advances made in tropical cyclone track prediction at the Met. Office.

The Met. Office web site is:- <http://www.meto.govt.uk>

Tropical Cyclone information can be found under the section "The weather & how we forecast it".

The information above is also available on the Met. Office internal web under Julian Heming's home page. Contact Julian Heming (jheming@meto.govt.uk) or Alan Radford (amradford@meto.govt.uk) for further information on tropical cyclone forecasting at the Met. Office.

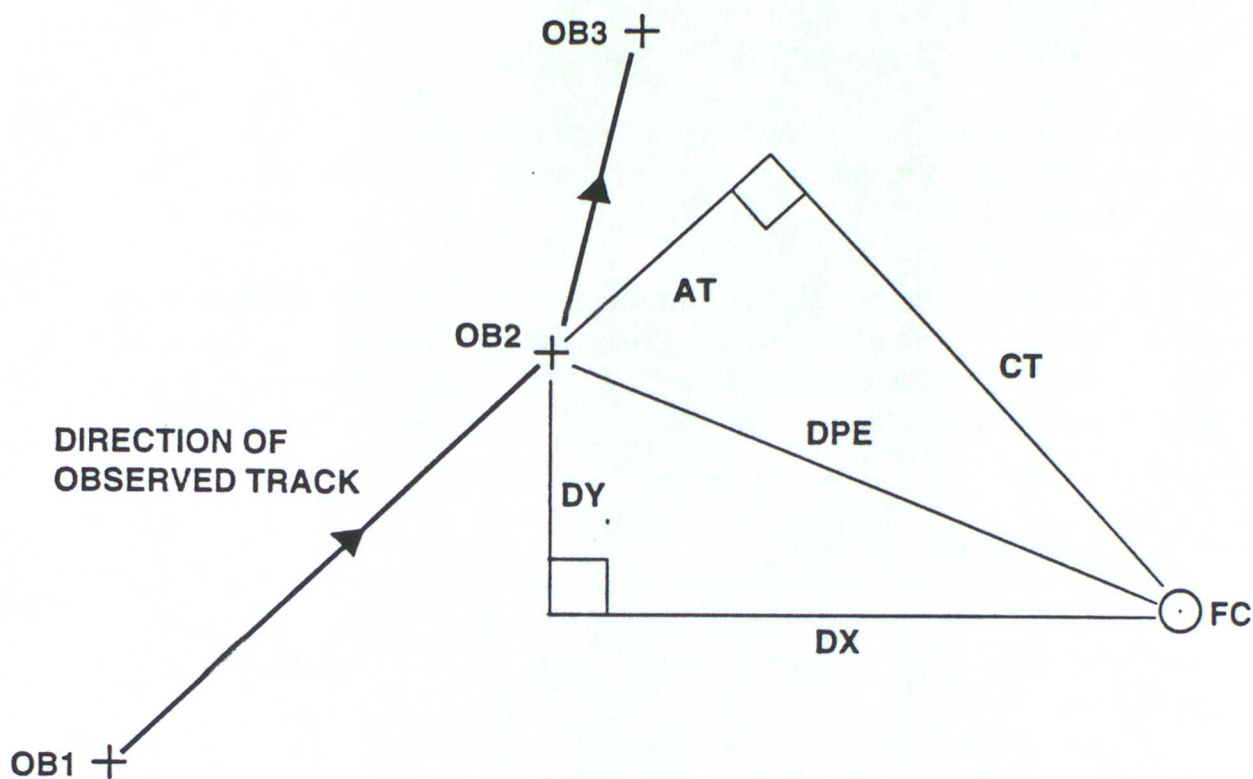
Acknowledgements

CLIPER models for various basins were supplied by Mr.S.Lord, NMC, Washington, USA and Mr.C.Mauck, FNOC, Monterey, USA. GrADS software used to produce track plotting charts was supplied by Mr.S.Lord and Dr.M.Fiorino.

Best track observations for the northern hemisphere were supplied by Mr.J.Gross, NHC, Miami, Mr.F.Wells, JTWC, Guam and Mr.S.Osano, JMA, Tokyo.

APPENDIX A

Diagrammatic Explanation of Forecast Errors



OB1-3 : Observed positions

FC : Forecast position verifying against observation OB2

DPE : Direct positional error

DX : Error in the East-West direction

DY : Error in the North-South direction

AT : Error in the Along Track direction

CT : Error in the Cross Track direction

All errors are measured in kilometres

Sign Conventions

DPE values are *always* positive.

DX errors are positive if the forecast position lies eastwards of the observed position.

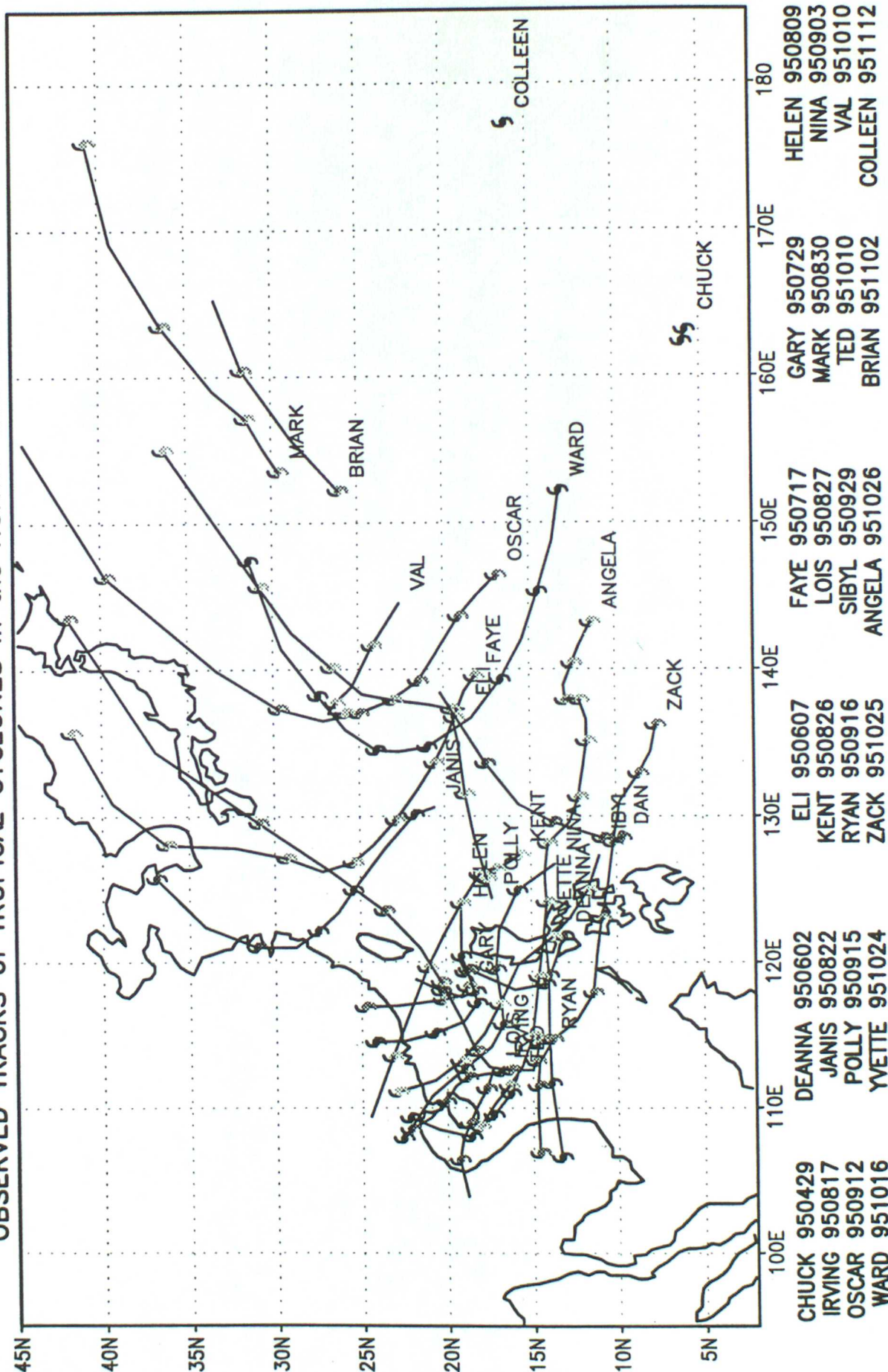
DY errors are positive if the forecast position lies polewards of the observed position.

AT errors are positive if the forecast position lies ahead of the observed position along the tropical cyclone track.

CT errors are positive if the forecast position lies right of the observed track in the northern hemisphere and left of the observed track in the southern hemisphere.

Figure 1

OBSERVED TRACKS of TROPICAL CYCLONES in the NORTH-WEST PACIFIC BASIN



KEY to DATE of FIRST SYMBOL

24 HOURLY BEST TRACK OBSERVED POSITIONS
SYMBOLS REPRESENT 12Z POSITIONS

Figure 2
North-West Pacific Tropical Cyclone Forecast Positional Errors

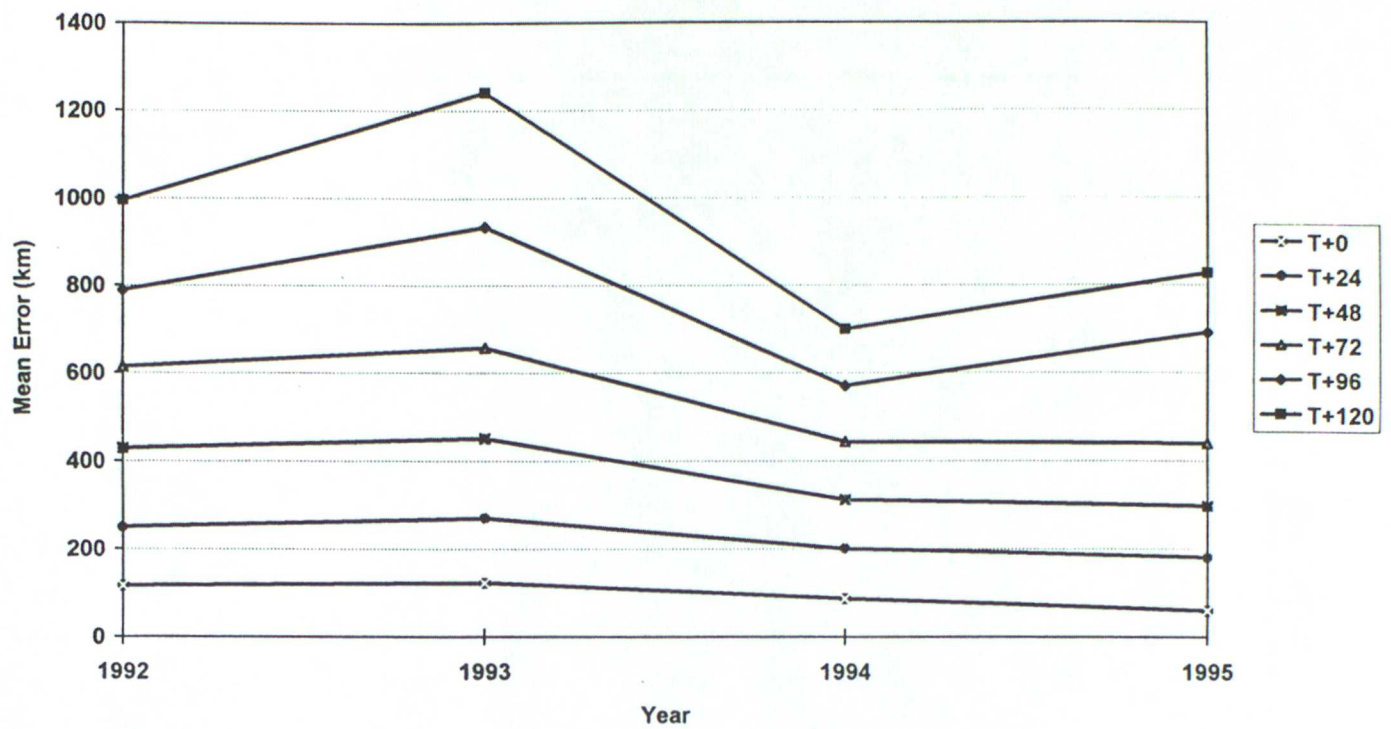


Figure 3
North-West Pacific Tropical Cyclone Forecast Skill against CLIPER

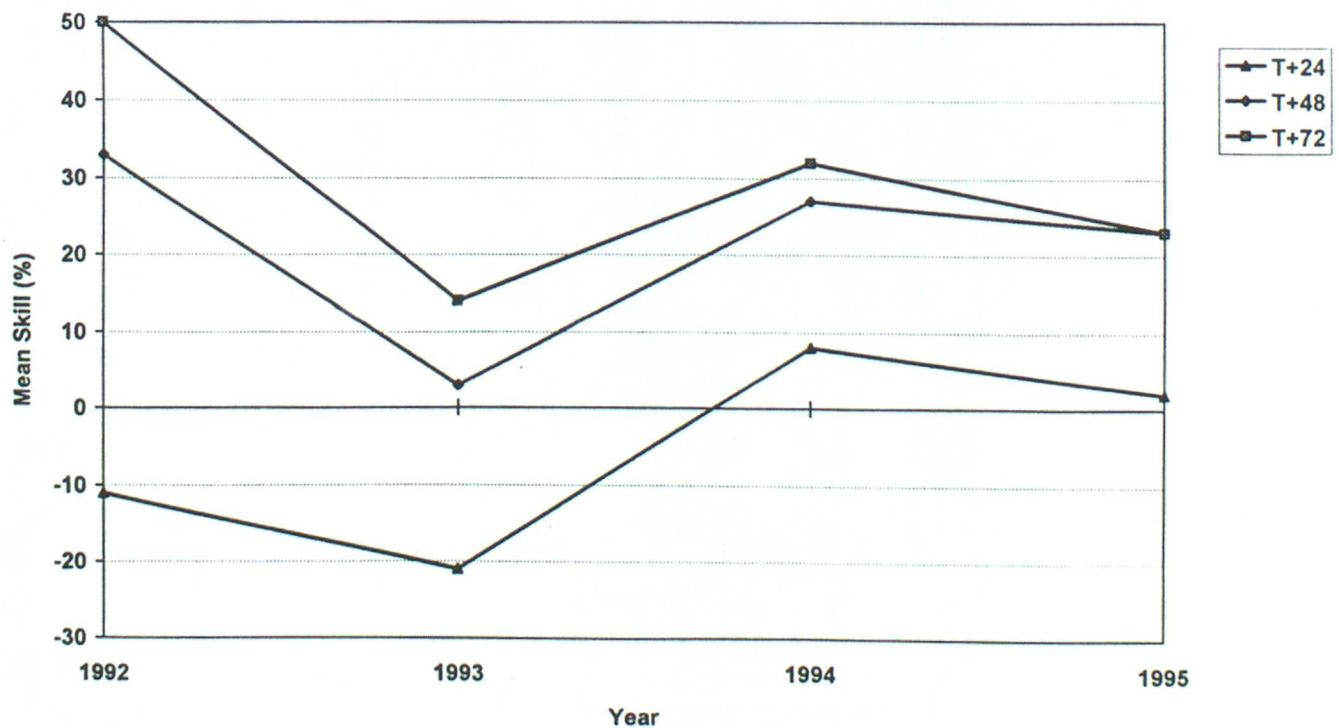
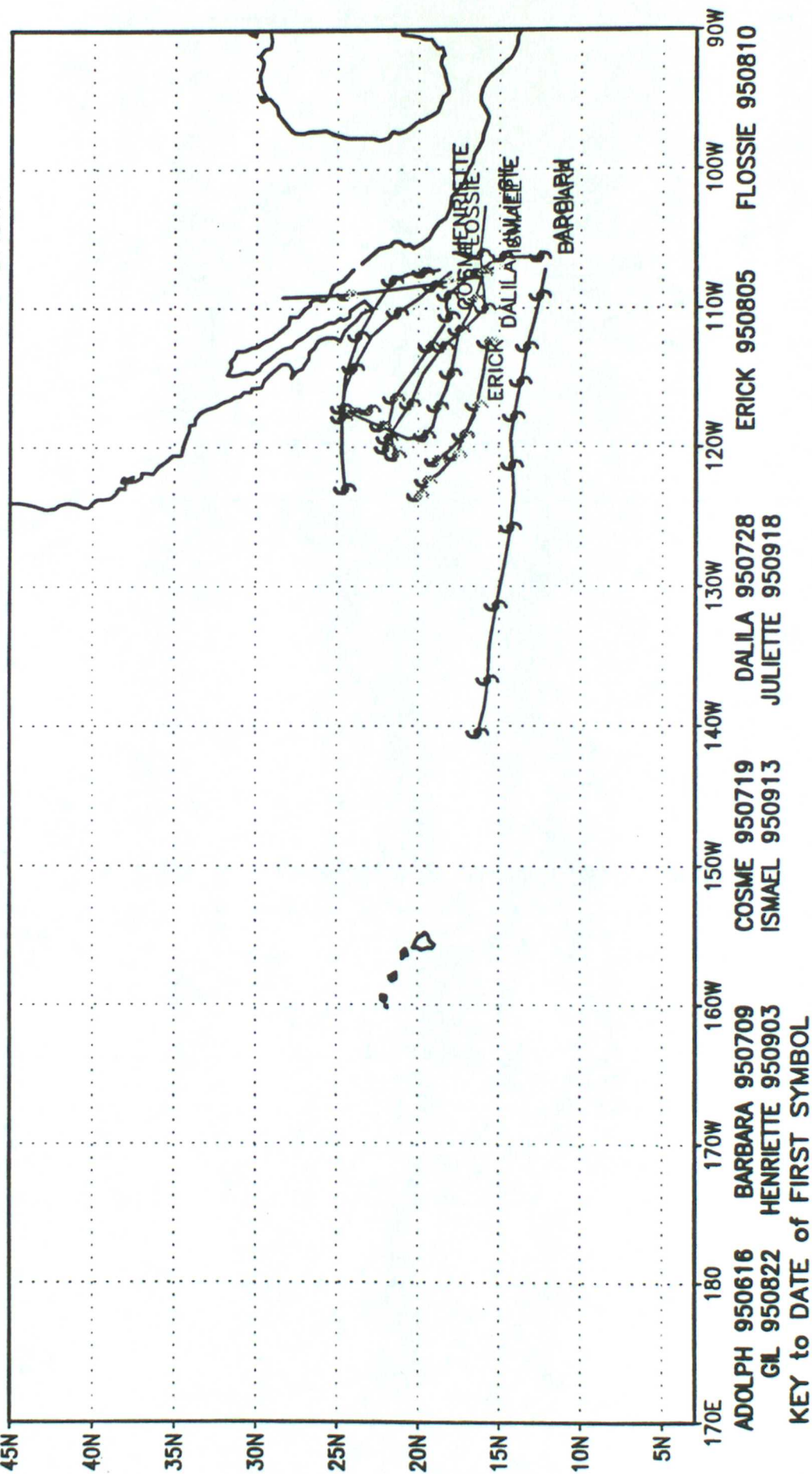


Figure 4

OBSERVED TRACKS of TROPICAL CYCLONES in the NORTH-EAST PACIFIC BASIN



24 HOURLY BEST TRACK OBSERVED POSITIONS
SYMBOLS REPRESENT 00Z POSITIONS

Figure 5
North-East Pacific Tropical Cyclone Forecast Positional Errors

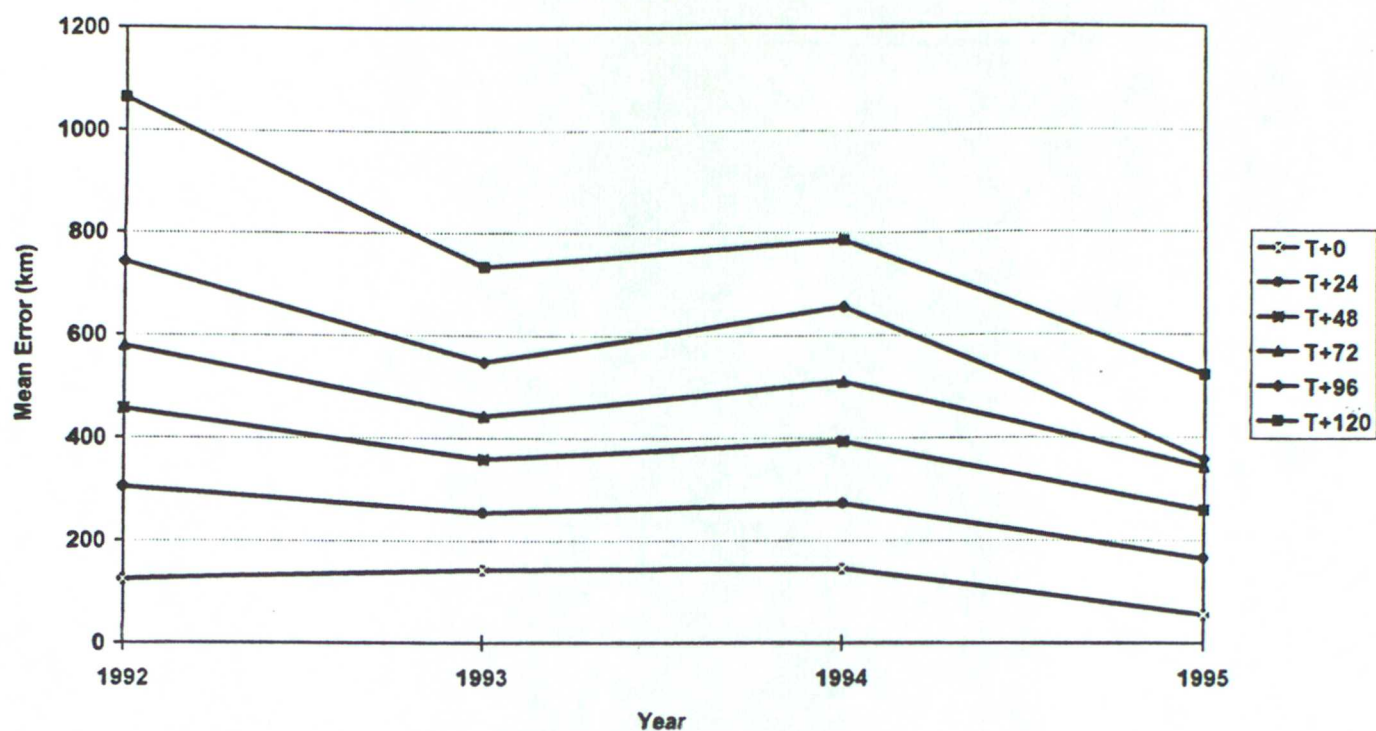


Figure 6
North-East Pacific Tropical Cyclone Forecast Skill against CLIPER

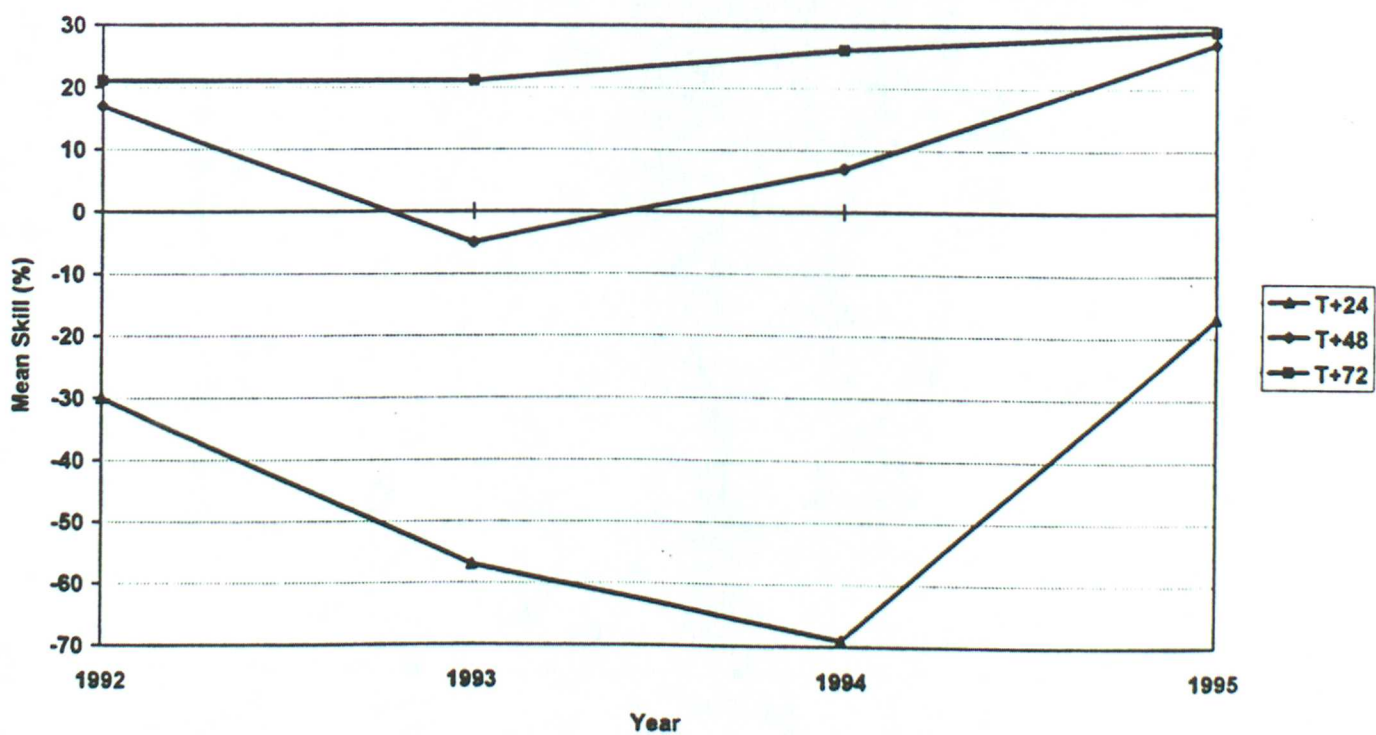
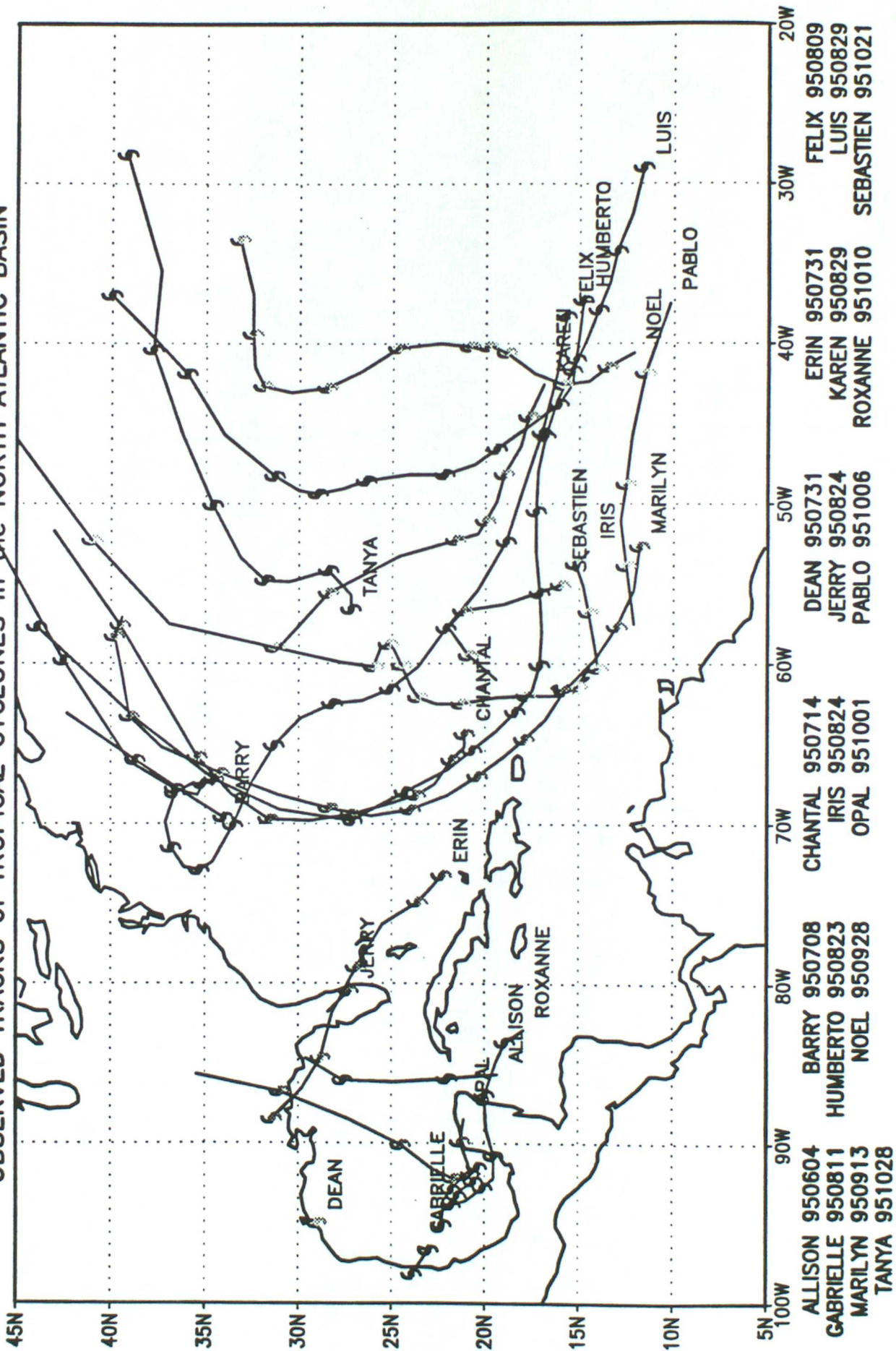


Figure 7

OBSERVED TRACKS of TROPICAL CYCLONES in the NORTH ATLANTIC BASIN



KEY to DATE of FIRST SYMBOL

24 HOURLY BEST TRACK OBSERVED POSITIONS
SYMBOLS REPRESENT 00Z POSITIONS

Figure 8
North Atlantic Tropical Cyclone Forecast Positional Errors

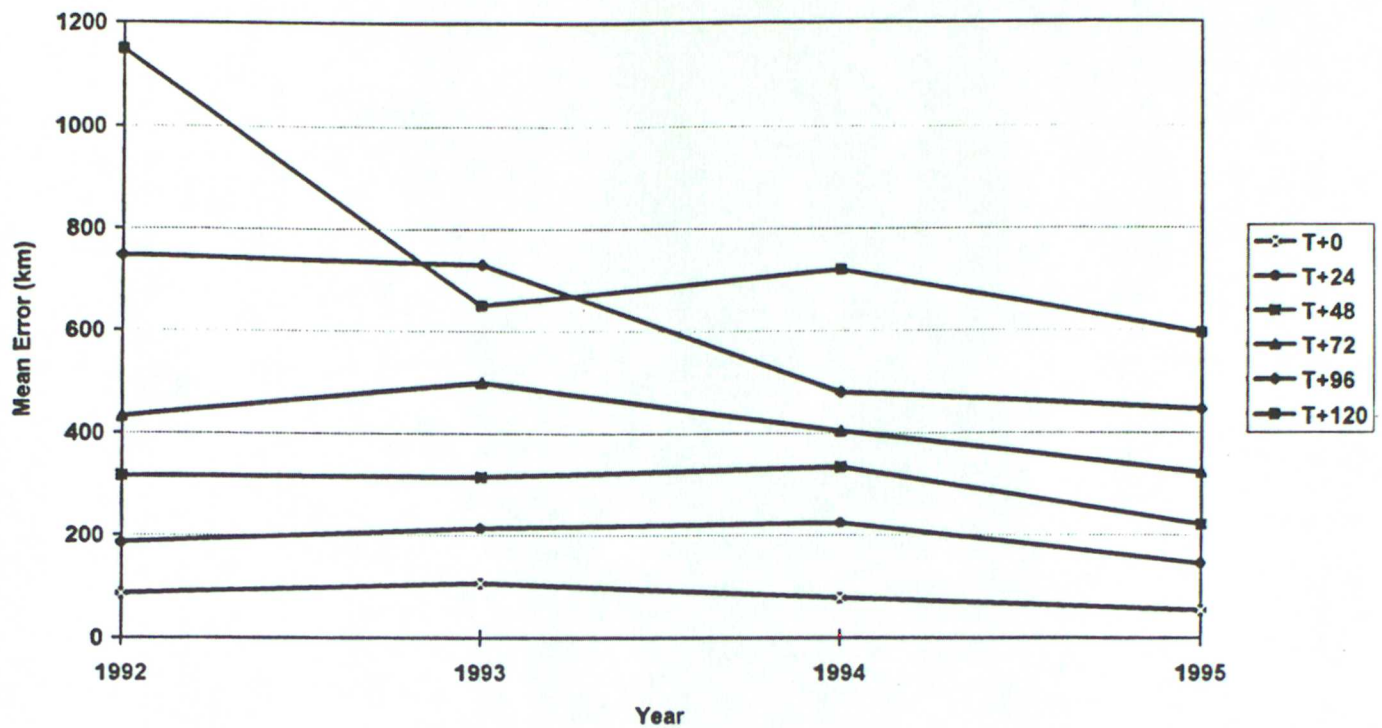


Figure 9
North Atlantic Tropical Cyclone Forecast Skill against CLIPER

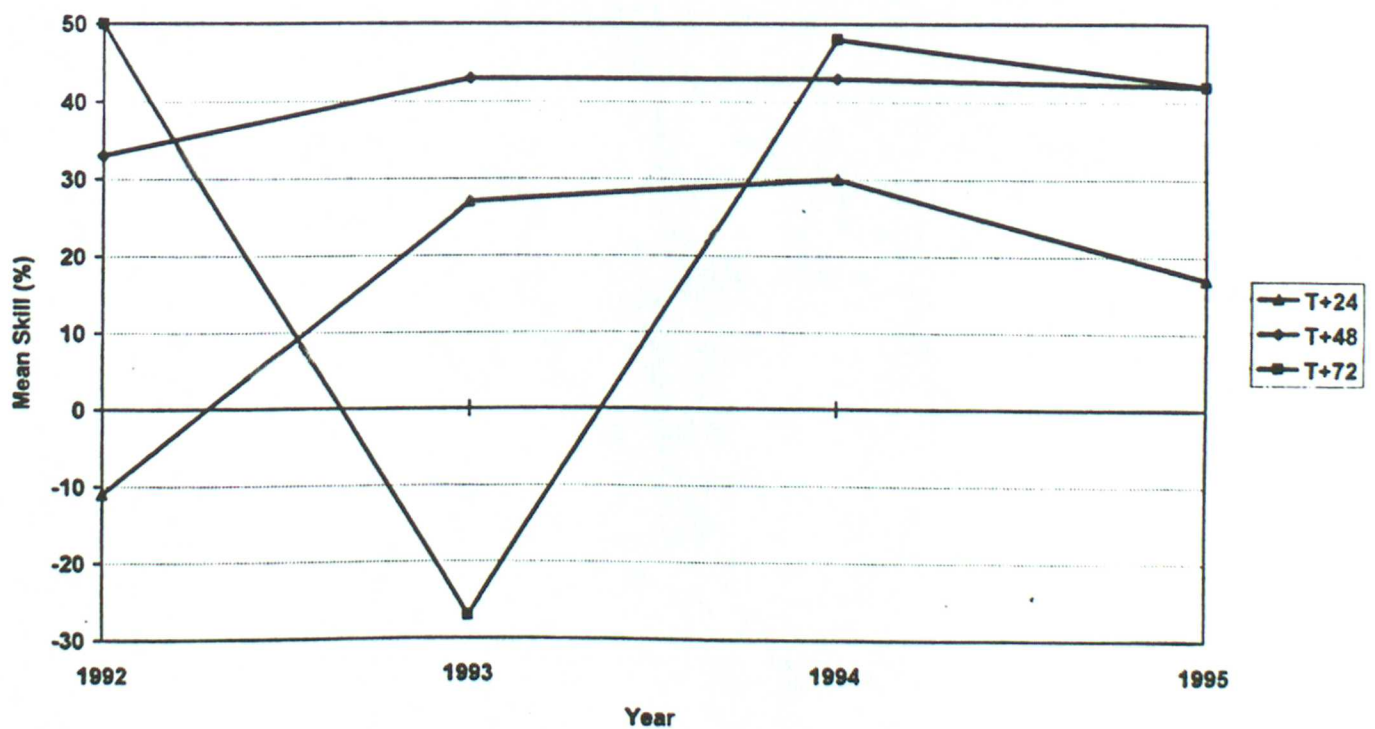
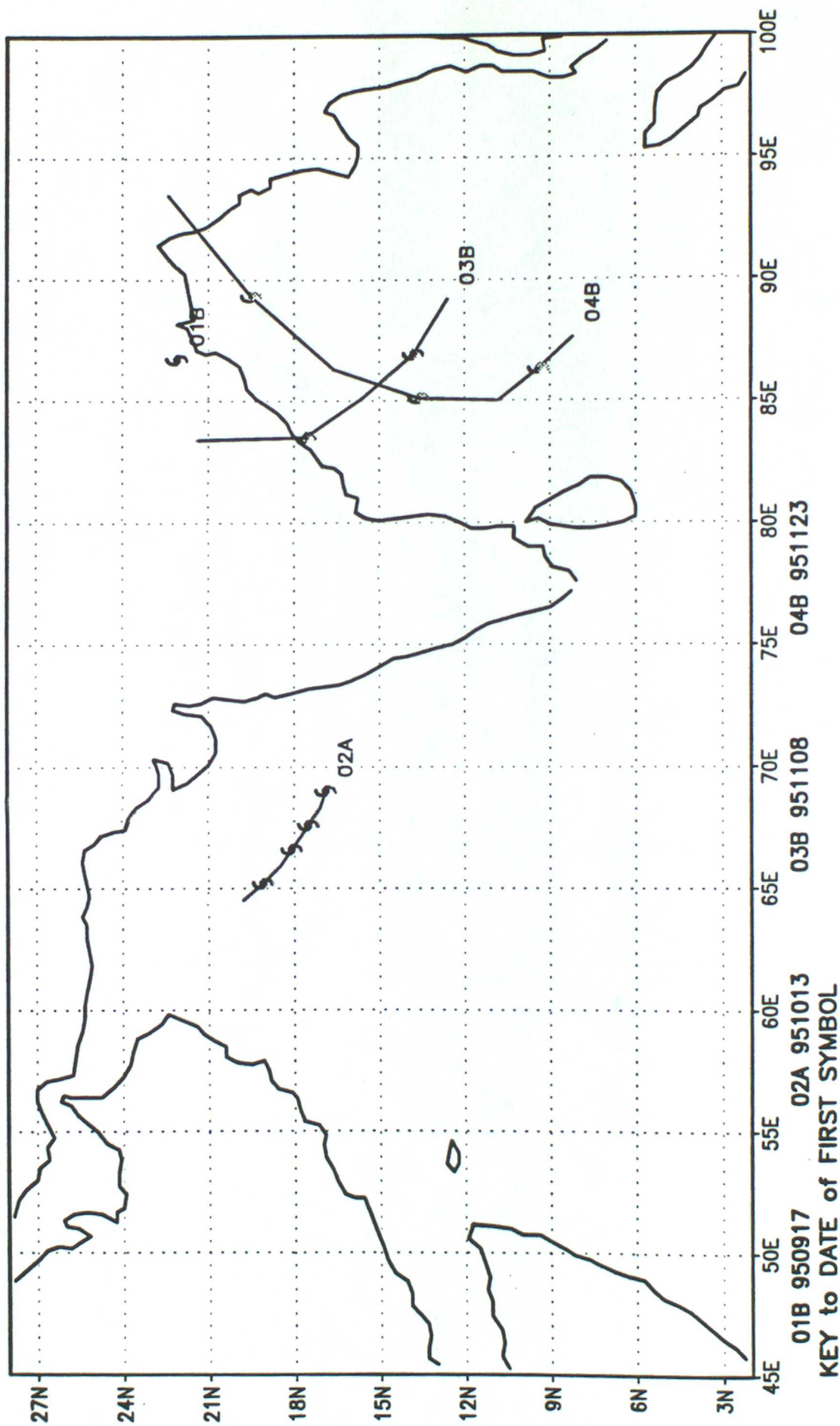


Figure 10

OBSERVED TRACKS of TROPICAL CYCLONES in the NORTH INDIAN BASIN



24 HOURLY BEST TRACK OBSERVED POSITIONS
SYMBOLS REPRESENT 00Z POSITIONS

Figure 11
North Indian Tropical Cyclone Forecast Positional Errors

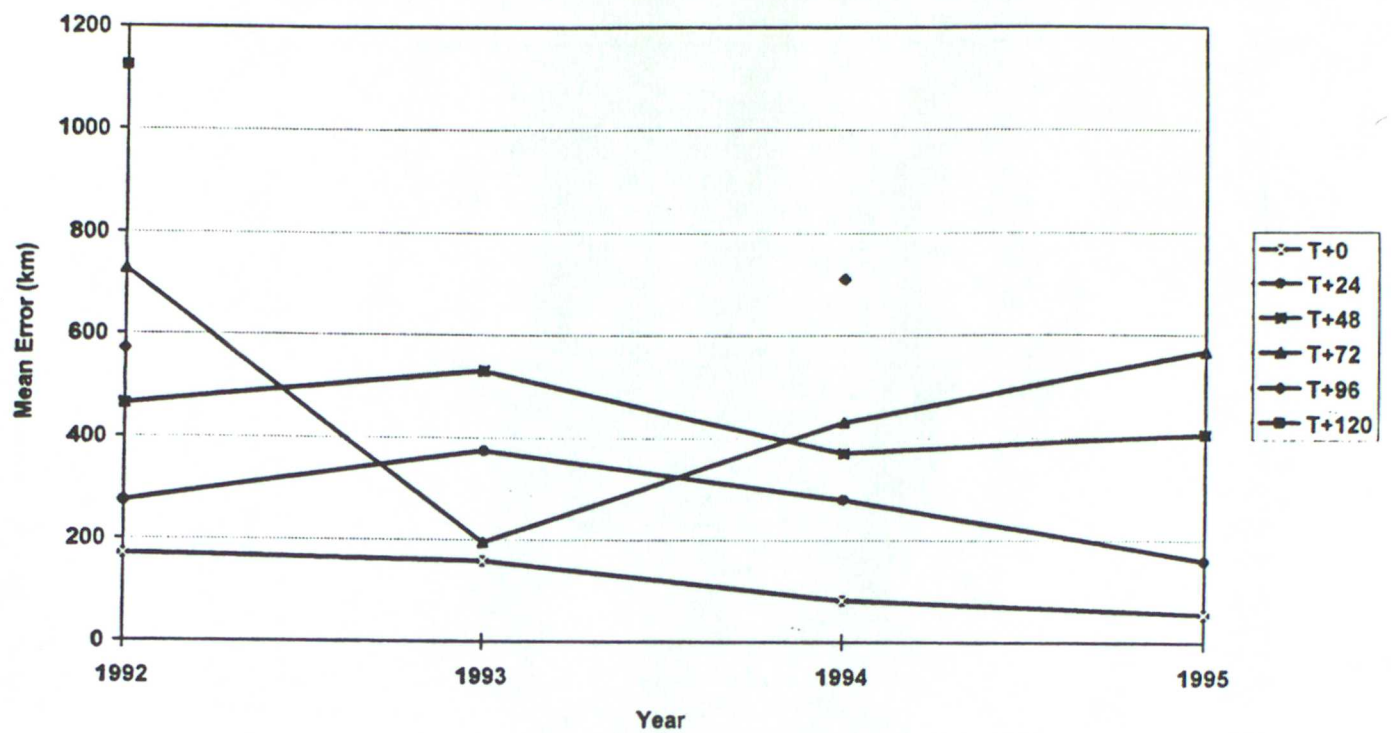


Figure 12
North Indian Tropical Cyclone Forecast Skill against CLIPER

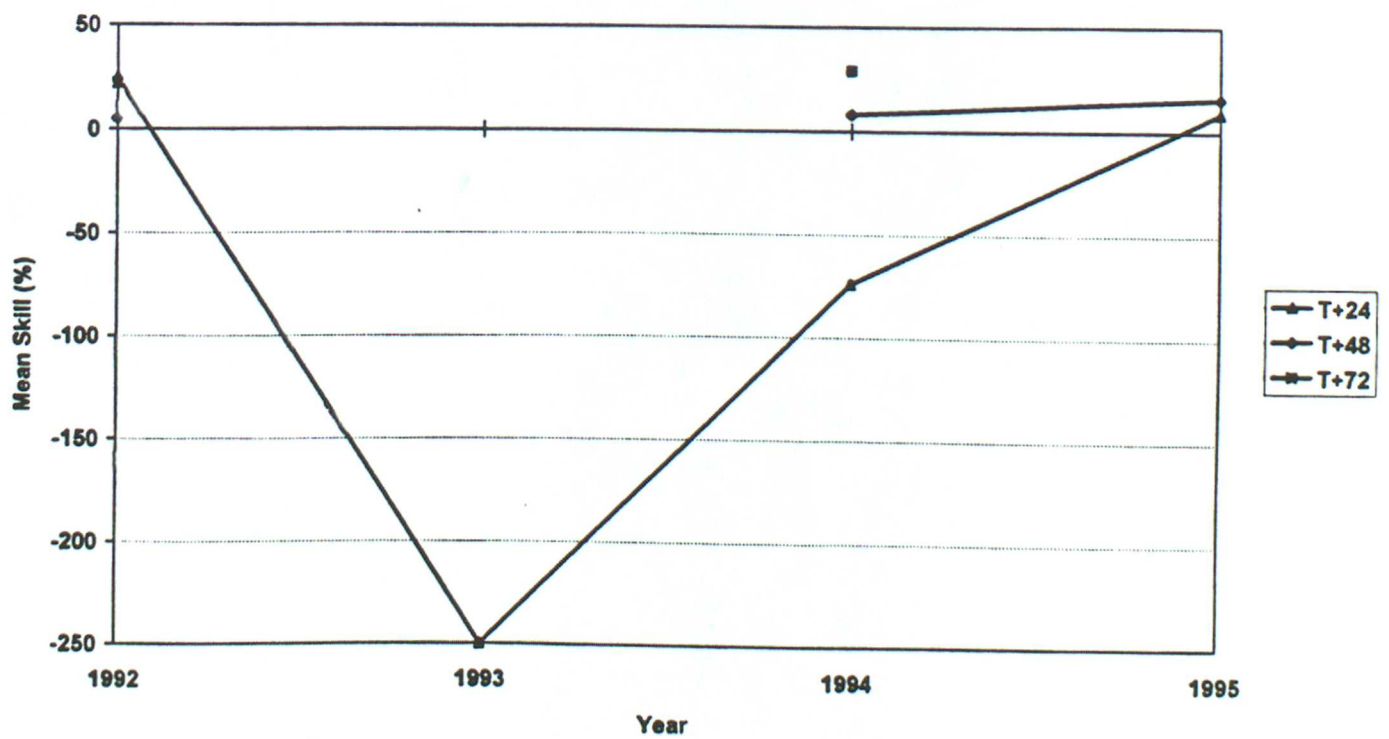


Figure 13
Northern Hemisphere Tropical Cyclone Forecast Positional Errors

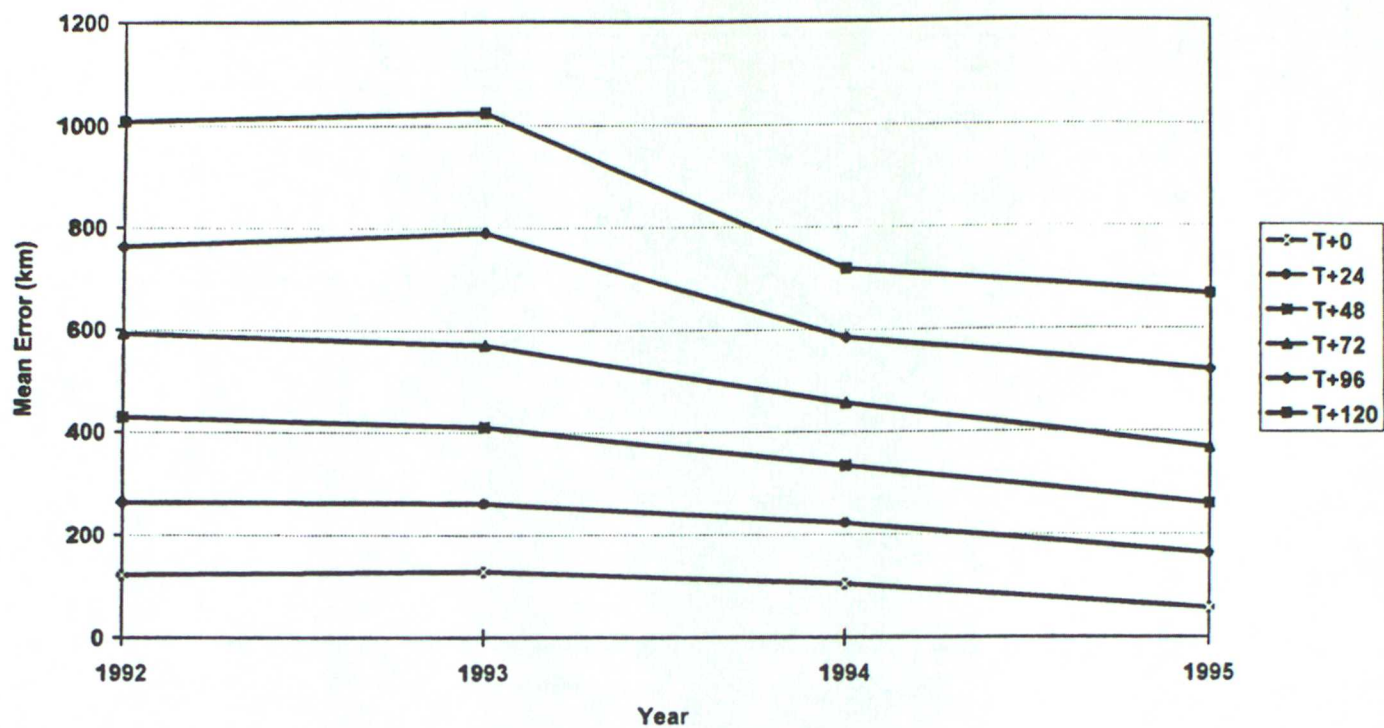


Figure 14
Northern Hemisphere Tropical Cyclone Forecast Skill against CLIPER

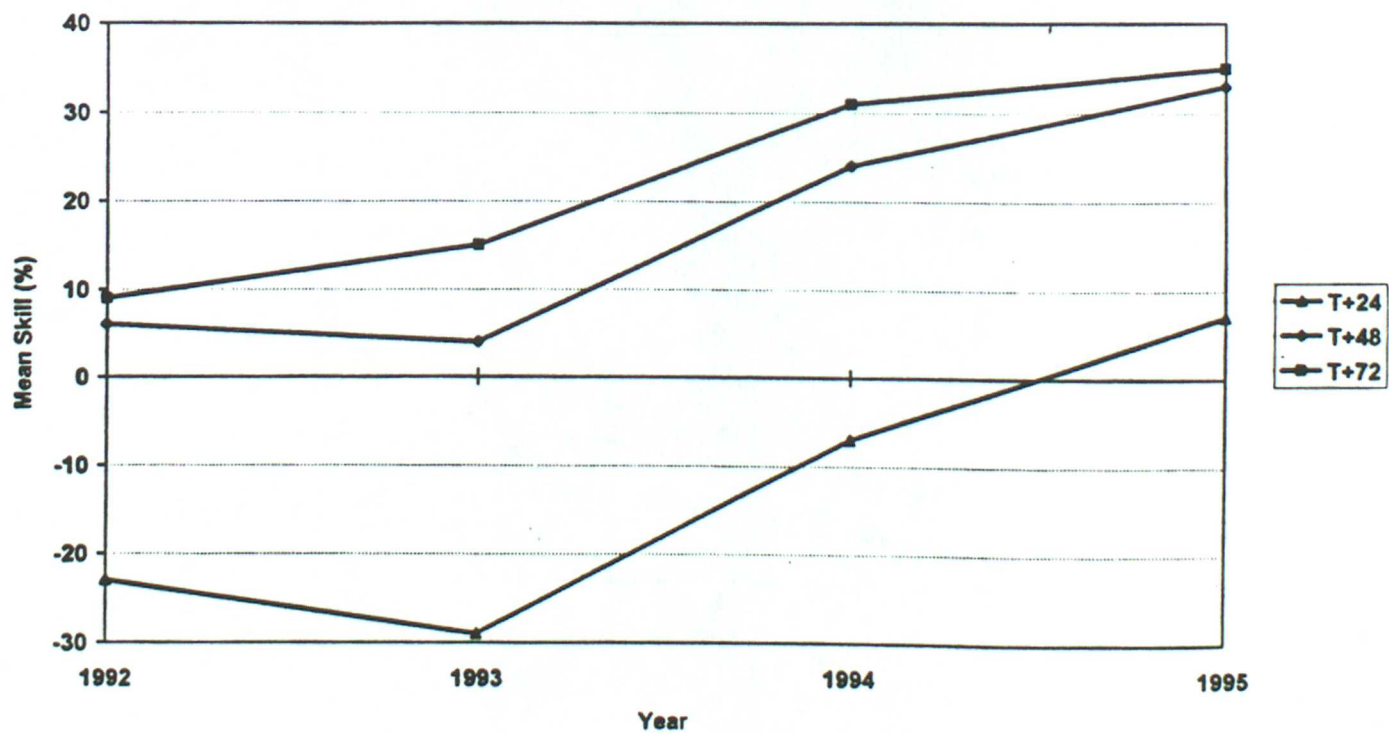


Figure 15
Northern Hemisphere Tropical Cyclone Along-Track Forecast Errors

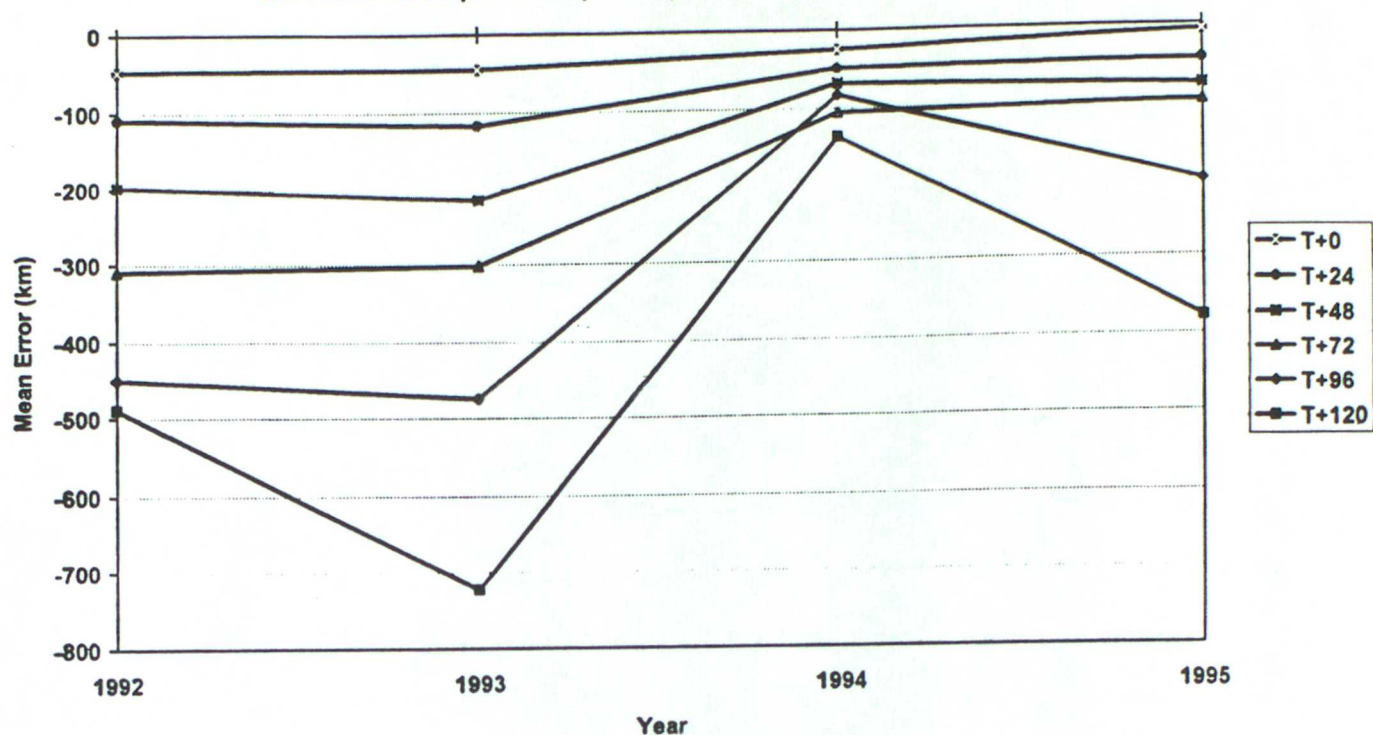


Figure 16
Northern Hemisphere Tropical Cyclone Cross-Track Forecast Errors

